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Assessment of Renal Resistive Index in Hypertensive Adults at Central Hospital Ughelli, Delta State, Nigeria

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Abstract **Original Research Article**

Background: Constant high blood pressure leads to changes in the blood vessels of the kidneys, which can reduce blood flow and cause gradual kidney damage. The Renal Resistive Index (RRI), measured through Doppler ultrasound, is a safe and non-invasive method that shows the resistance of blood flow in the kidney vessels. It can help detect early signs of kidney problems before serious damage occurs. This study aimed to assess RRI in adults with clinically diagnosed hypertension and to compare the results with those of healthy individuals.

Materials and methods: Prospective experimental study was conducted among 201 participants, which comprises of hypertensive adults (experimental group) and 100 normotensive (healthy) as the control group. Renal Doppler ultrasound was performed using standard procedures to measure RRI from the interlobar arteries of both kidneys. Both descriptive and inferential statistical tools were used for data analysis and level of significance was set at $p < 0.05$.

Results: The mean age, height, weight and body mass index, were 48.8 years, 170.4cm 75.2kg and 25.78kg/m^2 respectively. The mean Systolic BP, Diastolic BP, Left kidney RI and Right kidney RI were 148.8 ± 25.7mmHg, 92.3 ± 18.5mmHg, 0.68 ± 0.07 and 0.67 ± 0.07 respectively for the participants, The mean age for hypertensive subject was 53.4 ± 12.9 years while that of normotensives was 44.2 ± 15.6 years, the mean height for hypertensive subjects was 170.2 ± 8.7cm while that of the normotensives was 170.6 ± 8.6cm. The average RRI values were found to be significantly higher in hypertensive patients than in the normotensive group ($p < 0.001$).

Conclusion: Hypertension increases renal vascular resistance, suggesting early changes in kidney function even before visible signs of disease appear. Measuring RRI using Doppler ultrasound is a simple, reliable, and non-invasive method that can be used to detect, evaluate, and monitor kidney changes in hypertensive patients.

Keywords: Blood pressure, Doppler, renal, Ultrasound

INTRODUCTION

Hypertension is a significant global health burden among adults. It is estimated that around 1.28 billion adults aged 30–79 years are living with hypertension, yet 46% of them are unaware of their condition[1]. Hypertension remains the leading global cause of death, accounting for approximately 10.8 million preventable deaths and contributing to an estimated 235 million deaths and disabilities each year [1]. In Nigeria, the number of hypertension cases was about 20 million in 2010 and is projected to rise to 29.1 million by 2030. Hypertension, defined as a sustained elevation of systolic and/or diastolic blood pressure above 140/90 mm Hg after repeated measurements, can be classified into primary (essential) and secondary types. Essential hypertension, which accounts for approximately 95% of all cases, is characterized by elevated blood pressure not attributable to any identifiable co-existing medical condition and arises from a combination of genetic, environmental, and lifestyle factors [2]. In contrast, secondary hypertension results from underlying medical conditions such as renal disease, cardiovascular disorders, or diabetes. Regardless of the type, untreated hypertension can lead to serious complications, including target organ damage [3]. Studies have demonstrated that individuals of African descent are more likely to develop hypertension-related organ damage at an earlier age and with greater resistance to treatment compared to non-Black populations, underscoring the influence of race and ethnicity on the prevalence, progression, and management of hypertension[4].

Hypertension affects the kidneys by damaging the glomeruli, causing swelling of the endothelial cells, loss of tiny pores (fenestrae), and blockage of the capillary spaces [5]. These changes reduce blood flow, create instability in kidney circulation, and can lead to kidney dysfunction[6]. Managing hypertension effectively requires controlling blood pressure and checking for organ damage, with kidney blood flow assessment being especially important[7].

In clinical practice, there is no universally accepted gold-standard imaging modality for assessing renal perfusion. Available techniques include renal scintigraphy, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound. Among these, ultrasound is preferred due to its safety, cost-effectiveness, and accessibility [8]. While conventional ultrasound provides information on renal morphology, Doppler ultrasound is particularly important for evaluating renal blood flow abnormalities and intrarenal perfusion changes associated with parenchymal and systemic hemodynamic disorders [9].

Renal perfusion can be assessed using intrarenal artery Doppler indices, particularly the pulsatility index (PI) and the renal resistive index (RRI). Of the two, the RRI is considered the more reliable and clinically useful predictor of acute kidney injury and long-term outcomes, as it demonstrates lower variability (4.2–7%) compared to the PI (9.5–22.7% [10]. Consequently, the RRI has become the most preferred index in clinical practice, as it remains a sensitive and reproducible marker for detecting renal and cardiovascular disease–related perfusion abnormalities, despite certain limitations. The Renal Resistive Index (RRI), obtained through Doppler ultrasound, has gained recognition as a valuable parameter in the evaluation of hypertensive disease. In cases of secondary hypertension, it provides important insights into renal hemodynamics, while in essential hypertension; it goes beyond conventional markers of glomerulopathy by reflecting the progression of renal damage. Moreover, RRI has been shown to predict both cardiovascular and renal outcomes, emphasizing its prognostic significance. Its role has also been highlighted in the complex assessment of resistant hypertension. Because Doppler evaluation of RRI is straightforward, requires minimal training, and is highly reproducible, it is increasingly regarded as a practical, multifunctional tool for assessing overall cardiovascular and renal risk in hypertensive patients. Nevertheless, larger, prospective population-based studies are still needed to confirm and strengthen these findings[11].

In low-income countries like Nigeria, access to modern methods for assessing the risk of organ damage from hypertension can be limited, making alternative approaches necessary. One such method is the use of intrarenal arterial Doppler flow, which can detect early changes in arterial resistance an early sign of renovascular hypertension. This makes it valuable for monitoring patients with hypertension to prevent or delay kidney damage [12]. Although studies have examined the renal artery Doppler resistive index (RRI) in normotensive and hypertensive individuals, RRI values have been found to vary across different populations, likely due to genetic and environmental factors [12]. This highlights the need for population-specific RRI reference values. Because such data are limited in our region, this study was designed to compare RRI between normotensive and hypertensive individuals in Ughelli, Delta state, Nigeria and to explore its relationship with age, body mass index (BMI), systolic blood pressure and diastolic blood pressure.

MATERIAL AND METHODS

This prospective cross-sectional study, which includes 101 in adult hypertensive and 100 normotensive patients respectively, was conducted at the Radiology Department of Central Hospital Ughelli, Delta State, Nigeria. The hospital is a referral center that caters for a wide range of patients, including those with cardiovascular and renal disorders. The radiology department is well-equipped with high-resolution Doppler ultrasonography machines and experienced Radiologists and Radiographers. Ethical approval with the reference number (HM/596/T^2/50) was obtained from the Ministry of Health, Delta State, Nigeria. Written informed consent was obtained from the participants before recruitment into the study. The study was conducted in accordance with the ethical principles of Helsinki Declaration. Only those who consented to the study were included in the study. The purpose of the study was adequately explained to the participants and their participation was entirely voluntary.

The instruments for data collection includes; anthropometric measurement tools**,** weighing scale and stadiometer to measure weight (kg) and height (m). Sphygmomanometer. High resolution Mindray DC -70 and Sonoace X8 ultrasound machines with pulsed-wave Doppler capability and a 3.5–5.0 MHz convex probe.

Weight and height were measured using weighing scale and stadiometer and BMI was calculated as weight (in kg) divided by height (height in meter squared). Blood pressure measurement was performed with a calibrated sphygmomanometer after the patient has rested for 5 minutes. High resolution Mindray DC -70 and Sonoace X8 ultrasound machine with pulsed-wave Doppler capability and a 3.5–5.0 MHz convex probe were used.

Each participant was examined in the supine and left posterior oblique positions. Both kidneys were scanned in longitudinal and transverse planes. Renal length, parenchymal thickness, and echogenicity were documented. Doppler sampling was done from segmental, interlobar, and arcuate arteries at the upper, middle, and lower poles of each kidney. The Doppler angle of insonation was kept ≤60°. At least three reproducible waveforms with good spectral filling were obtained. The peak systolic velocity (PSV) and end-diastolic velocity (EDV) were measured. The renal resistive index (RRI) was calculated automatically by the machine using the formula: Renal Resistive Index = Peak Systolic Velocity – End Diastolic Velocity/Peak Systolic Velocity. The average RRI for each kidney was obtained from three measurements each for the upper, mid, and lower pole. The mean RRI of the two kidneys was also computed.

Data analysis was performed using MedCalc Statistical Software version 23.3.7(MedCalc Software Ltd, Ostend, Belgium). Data were first subjected to the Shapiro- Wilk test for normality check. Continuous variables with normal distribution were analyzed using parametric tests, while those with non-normal distribution were analyzed using non-parametric tests. Categorical variables were expressed as frequencies and percentages. The comparison between the groups was conducted using the Mann Whitney U test. The kendall's Tau was used to test associations between RRI and continuous variables (age, SBP, DBP, BMI) and p-value <0.05 was considered statistically significant

RESULTS

The result showed that out of two hundred and one subjects , 101 are hypertensive adults, males constituted 51.5% (n=52) while female constituted 48.5% (n=49) and 100 Non hypertensive adults, males constituted 49.0% (n=49) while female constituted 51.0% (n=51). (Table 1). The mean age , height, weight and body mass index, were 48.8 years, 170.4cm 75.2kg and 25.78kg/m^2 respectively. The mean Systolic BP, Diastolic BP, Left kidney RI and Right kidney RI were 148.8 ± 25.7mmHg, 92.3 ± 18.5mmHg, 0.68 ± 0.07 and 0.67 ± 0.07 respectively for the participants (Table 2). From Table 3, the mean age for hypertensive subject was 53.4 ± 12.9 years while that of normotensives was 44.2 ± 15.6 years, the mean height for hypertensive subjects was 170.2 ± 8.7cm while that of the normotensives was 170.6 ± 8.6cm, the mean weight for hypertensive subjects was 78.6 ± 18.1kg while that of normotensives was 71.7 ± 10.5kg, the mean body mass index for hypertensives was 26.9 ± 4.9kg/m^2 while that of normotensives was 24.6 ± 3.0kg/m^2 , the mean systolic blood pressure for hypertensive subjects was 168.4 ± 22.1mmHg while that of normotensives was 129.1 ± 7.6mmHg, the mean diastolic blood pressure for hypertensive subjects was 106.2 ± 15.5mmHg while that of the normotensives was 106.2 ± 15.5mmHg, the mean left renal resistive index for hypertensives was 0.72 ± 0.07 while that of the normotensives was 0.63 ± 0.03, the mean right renal resistive index for hypertensive subjects was 0.71 ± 0.06 while that of normotensives was 0.62 ± 0.03, the mean composite renal resistive index for hypertensive subjects was 0.72 ± 0.06 while that of normotensives was 0.63 ± 0.02. Table 4 shows the comparison between the right kidney RI, left kidney RI and composite kidney RI for hypertensive subjects and normotensives using Mann-Whitney U test, from the table, the left kidney RI for normotensive and hypertensive subjects were 0.63 and 0.73 respectively (P-value <0.0001), right kidney RI for normotensive and hypertensive subjects were 0.62 and 0.71 respectively (P-value <0.0001), the composite kidney RI for the normotensive and hypertensive subjects were 0.63 and 0.72 respectively (P-value <0.0001).

Table 5 shows the correlation of the kendall's Tau (τ) of the Renal Resistive Indices with Age, BMI, Diastolic Blood Pressure and Systolic Blood Pressure. The kendall's Tau for the left renal resistive index and age was 0.209 (P<0.0001). The kendall's Tau for right renal resistive index and age was 0.248 (P<0.0001).The kendall's Tau for mean renal resistive index and age was 0.245 (P<0.0001). The kendall's Tau of the left renal resistive index and BMI was 0.0770 (P=0.1046). The kendall's Tau for the right renal resistive index and BMI was 0.0185 (P=0.6972). The kendall's Tau for the mean renal resistive index and BMI was 0.0664 (P= 0.1621). The kendall's Tau for the left renal resistive index and diastolic blood pressure was 0.442 (p < 0.0001). The kendall's Tau for the right renal resistive index and diastolic blood pressure was 0.395 (p< 0.0001). The kendall's Tau for mean renal resistive index and diastolic blood pressure was 0.450 (P<0.0001). The kendall's Tau for left renal resistive index and systolic blood pressure was 0.500 (p <0.0001). The kendall's Tau for right renal resistive index and systolic blood pressure was 0.442 (p<0.0001). The kendall's Tau for mean renal resistive index and systolic blood pressure was 0.519 (p<0.0001).

DISCUSSION

This study assessed the Renal Resistive Index (RRI) in adults with clinically diagnosed hypertension and compared it with that of normotensive controls using Doppler ultrasonography. It also examined the relationship between RRI, age, body mass index (BMI), systolic blood pressure and diastolic blood pressure. The results showed that hypertensive adults had higher RRI values than normotensive individuals, indicating increased resistance to blood flow within the kidneys. The study also found a weak positive relationship between RRI and both age and BMI, and a stronger correlation between RRI and systolic blood pressure. These findings suggest that high blood pressure has a greater influence on renal vascular resistance than other demographic factors such as age or body size.

The higher RRI values among hypertensive participants in this study agree with previous research showing that hypertension is a major cause of increased resistance in the renal blood vessels. Similar results were reported by Omolola et al.[13] (2012) and Madubueze and Ugwa[12] in Nigeria, who observed that hypertensive adults had significantly higher RRI than normotensive individuals. They explained that this difference results from structural and functional changes in the small arteries of the kidney due to high blood pressure. These changes include thickening of the vessel walls, narrowing of the lumen, and loss of elasticity, all of which reduce blood flow and increase resistance within the kidneys.

A related study by Abonyi et al[14] in Enugu also found that hypertensive adults had higher mean RRI values (0.71 ± 0.06) compared to normotensives (0.63 ± 0.03). Their findings support the current study and highlight the usefulness of RRI as a simple and early indicator of kidney involvement in hypertension. Likewise, Iyon et al[15] found that increased RRI is related to arterial stiffness and reduced vascular flexibility, which are common in people with hypertension.

Studies from other countries also support these findings. Ghafori et al[16] in Iran and Kasim et al[17] in Indonesia reported that hypertensive patients had higher RRI values and that these were linked to reduced kidney function as measured by the estimated glomerular filtration rate (eGFR). Clarisse et al[17] and Provenzano et al[19] also showed that people with elevated RRI were more likely to develop kidney disease and cardiovascular complications. These consistent findings from different populations confirm that increased RRI reflects both renal and systemic vascular problems caused by hypertension.

The weak correlation between RRI, age and BMI found in this study agrees with the work of Sidi et al. (2020), who reported that RRI increases slightly with age and weight among healthy adults. This is probably because aging and higher body weight cause gradual stiffening of blood vessels and reduced elasticity. However, these changes were not significant in this study, suggesting that high blood pressure remains the main factor affecting renal resistance. Abonyi et al[14] also found weak correlations between RRI, age, and BMI in their study, further supporting that hypertension has a stronger effect on renal hemodynamics than demographic factors.

The strong relationship between RRI and systolic blood pressure observed in this study agrees with the findings of Iyon et al[15], who also found that higher RRI values were associated with increased pulse pressure and arterial stiffness. This shows that as blood pressure rises, it causes the small arteries in the kidney to become less flexible, leading to reduced blood flow and higher RRI. Similarly, studies by Ghafori et al[16] and Provenzano et al[19] reported that higher RRI values were linked with microvascular damage and reduced kidney perfusion. This means that RRI can be used as an early and sensitive marker to detect kidney changes in hypertensive patients before serious damage occurs.

CONCLUSION

This study measured the Renal Resistive Index (RRI) in adults with hypertension and compared it with those of healthy people using Doppler ultrasound. The results showed that people with high blood pressure had higher RRI values in both kidneys than those without hypertension. This means that high blood pressure may cause early changes in the small blood vessels of the kidneys. The study also found that RRI increased with age and blood pressure, showing that older age and hypertension can affect kidney blood flow. However, there was little or no link between RRI and body mass index (BMI). This study shows that Doppler ultrasound measurement of RRI is a simple, affordable, and non-invasive way to detect early kidney changes in people with hypertension. Detecting these changes early can help doctors take timely action to prevent chronic kidney disease (CKD). Therefore, checking RRI during routine evaluation of hypertensive patients can improve care and outcomes, especially in areas with limited resources.

Conflict of interest: None declared among the authors

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Table 1: Frequency and percentage of gender distributions of the study participants

Gender	Frequency	percent
Hypertensive Patients		
Female	49	48.5(%)
Male	52	51.5(%)
Total	**101**	**100.0(%)**
Normotensive Healthy Subjects		
Female	51	51.0(%)
Male	49	49.0(%)
Total	**100**	**100.0(%)**

Table 2 Distribution of mean Renal Resistive Indices of the participants and other variables.

Parameter	Minimum	Maximum	Mean ± SD
Age (years)	19	74	48.8 ± 14.98
Height (cm)	150	195	170.4 ± 8.6
Weight (kg)	41	122	75.2 ± 15.2
BMI (Kg/m²)	16	39.8	25.78 ± 4.24
Systolic BP (mmHg)	100	210	148.8 ± 25.7
Diastolic BP (mmHg)	60	139	92.3 ± 18.5
Left kidney RI	0.52	0.89	0.68 ± 0.07
Right kidney RI	0.55	0.84	0.67 ± 0.07

Table 3 Comparison of the mean Renal Resistive Indices and other variables between hypertensive and normotensive subjects.

Hypertensive Patients

Parameter	Minimum	Maximum	Mean ± SD
Age (years)	19	74	53.4 ± 12.9
Height (cm)	150	186	170.2 ± 8.7
Weight (kg)	41	122.2	78.6 ± 18.1
BMI (Kg/m²)	16	39.8	26.9 ± 4.9
Systolic BP (mmHg)	123	210	168.4 ± 22.1
Diastolic BP (mmHg)	76	139	106.2 ± 15.5
Left kidney RI	0.52	0.89	0.72 ± 0.07
Right kidney RI	0.60	0.84	0.71 ± 0.06
Composite kidney RI	0.58	0.86	0.72 ± 0.06

Normotensive Healthy Subjects

Parameter	Minimum	Maximum	Mean ± SD

Age (years)	19	70	44.2 ± 15.6
Height (cm)	153.2	195	170.6 ± 8.6
Weight (kg)	47.9	99.6	71.7 ± 10.5
BMI (Kg/m²)	18.0	31.4	24.6 ± 3.0
Systolic BP (mmHg)	100	139	129.1 ± 7.6
Diastolic BP (mmHg)	60	89	78.3 ± 7.2
Left kidney RI	0.56	0.70	0.63 ± 0.03
Right kidney RI	0.55	0.70	0.62 ± 0.03
Composite kidney RI	0.57	0.70	0.63 ± 0.02

Table 4 : Comparison of the median values of the Renal Resistive Indices (RRI) Between Normotensive and Hypertensive Participants using Mann- Whitney U test

Parameter	**Mann–Whitney U Test**		
	Median Value		**P-value**
	Normotensive	Hypertensive	
Left kidney RI	0.63	0.73	<0.0001
Right kidney RI	0.62	0.71	<0.0001
Composite kidney RI	0.63	0.72	<0.0001

Table 5: Correlation of the kendall's Tau of the renal resistive indices with age, BMI, diastolic blood pressure and systolic blood pressure.

	Left kidney RI		RIGHT kidney RI		Composite kidney RI	
	τ	**p-value**	**τ**	**p-value**	**τ**	**p-value**
Age(years)	0.209	P<0.0001	0.248	P<0.0001	0.245	P<0.0001
BMI (Kg/m^2)	0.077	P=0.1046	0185	P=0.6972	0.0664	P=0.1621
DBP(mmHg)	0.442	P<0.0001	0.395	P<0.0001	0.450	P<0.0001
SBP(mmHg)	0.500	P<0.0001	0.442	P<0.0001	0.519	P<0.0001

Note. τ =kendall's Tau